APPENDIX D: EPA/ORD COAL INHALATION TOXICITY TESTING

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NERC ESAC Meeting, June 2003

EPA/ORD Coal Inhalation Toxicity Testing

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ESAC Meeting
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Background

- Engineering – emissions characterization, evaluation of different fuels, metals in waste and toxics studies
- Health – use of instillation, experience with metals and ROFA, focus on toxicity and susceptibility models
- Facilities developed to support these activities, capabilities

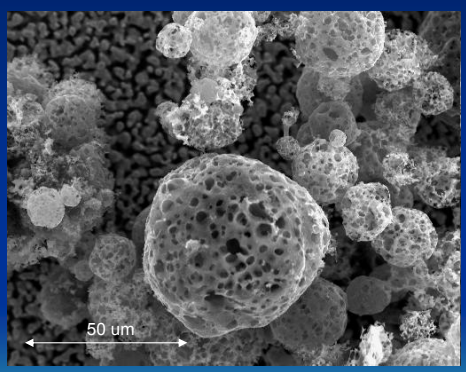
EPA Combustion Equipment

Institutional - North American Model firetube package boiler

Industrial model -Rainbow Boiler

Differences in Particle Morphology

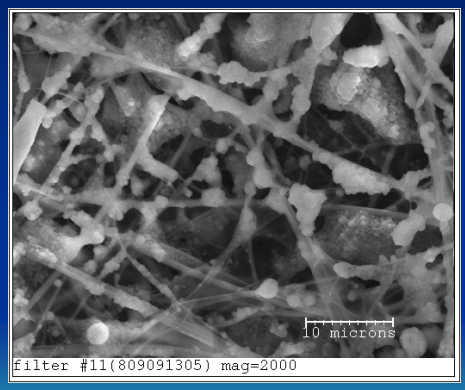
Cenospheres from Firetube Boiler



High unburned carbon
High mass in coarse fraction
Some metals retained in carbonaceous matrix

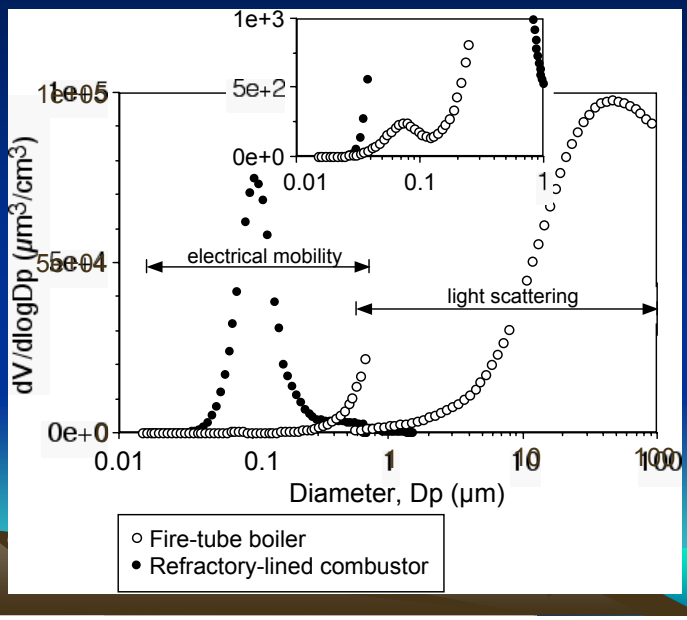
Differences in Particle Morphology

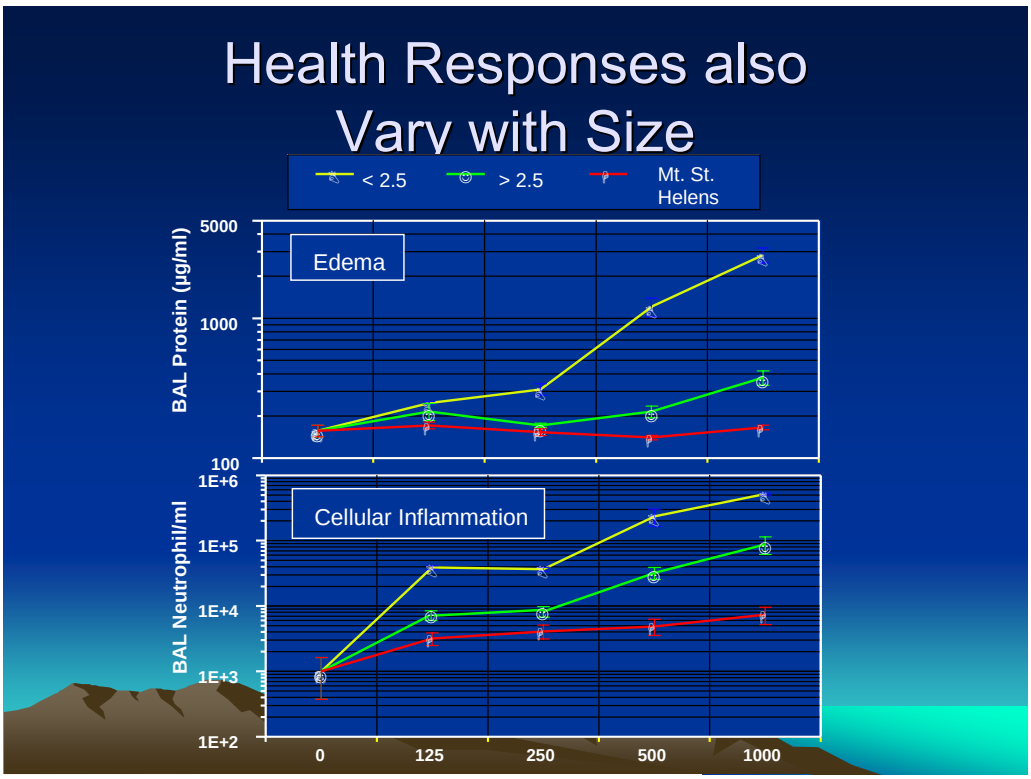
Fine and Ultrafine PM from Tunnel Furnace on Filter

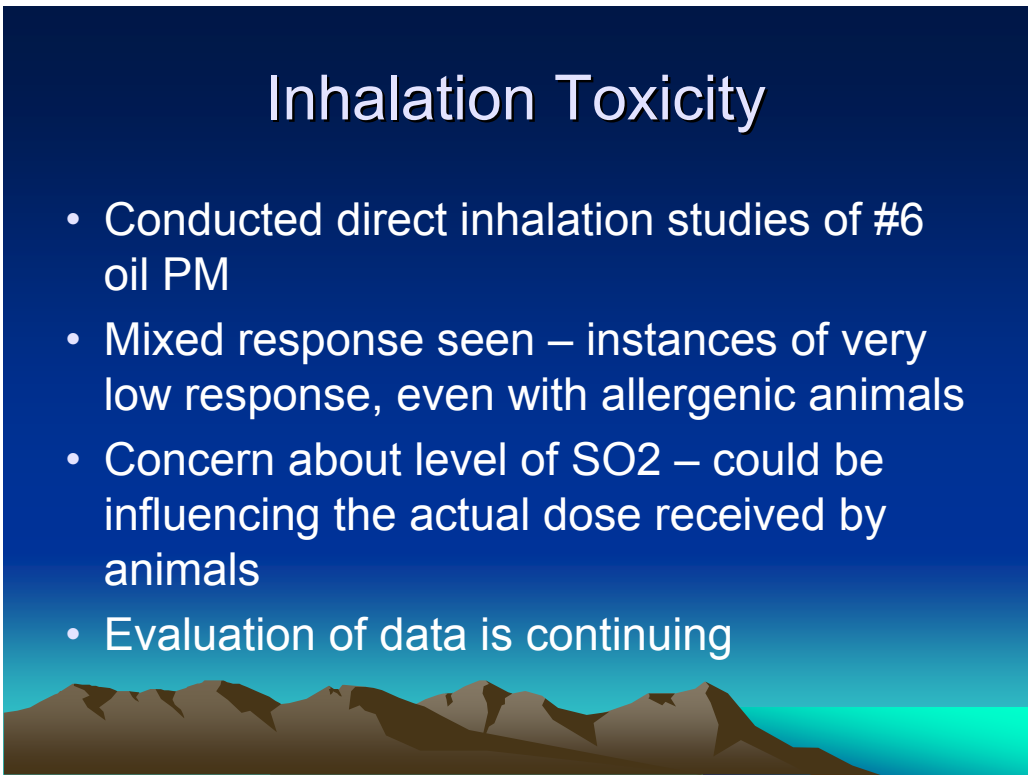


Low unburned carbon
Almost no mass in coarse fraction
Nearly all metals released into vaporization/condensation/ nucleation environment

PSDs for Oil Demonstrate Differences in Size for Different Conditions



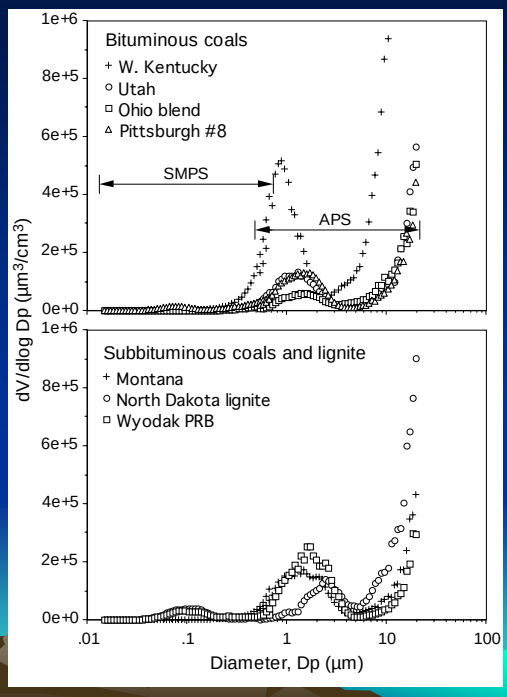

Health Responses also Vary with Size
< 2.5
> 2.5
Mt. St. Helens
Edema
BAL Protein (µg/ml)
5000
1000
100
Cellular Inflammation
BAL Neutrophil/ml
1E+6
1E+5
1E+4
1E+3
1E+2
0
125
250
500
1000

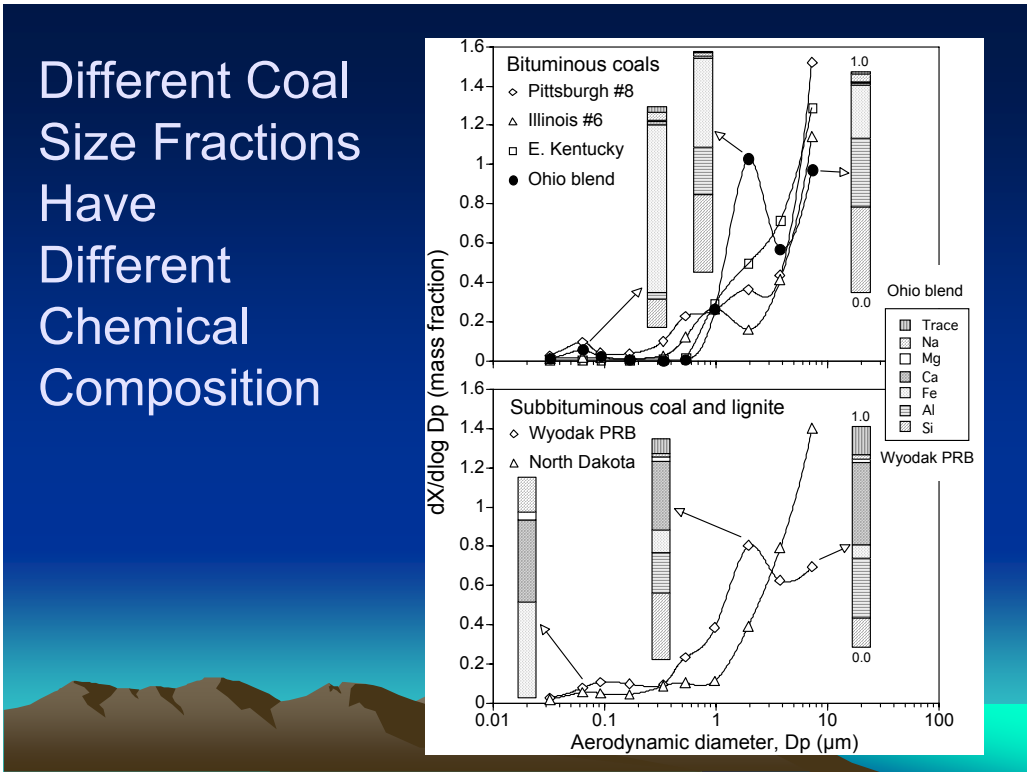

Inhalation Toxicity
• Conducted direct inhalation studies of #6 oil PM
• Mixed response seen – instances of very low response, even with allergenic animals
• Concern about level of SO2 – could be influencing the actual dose received by animals
• Evaluation of data is continuing

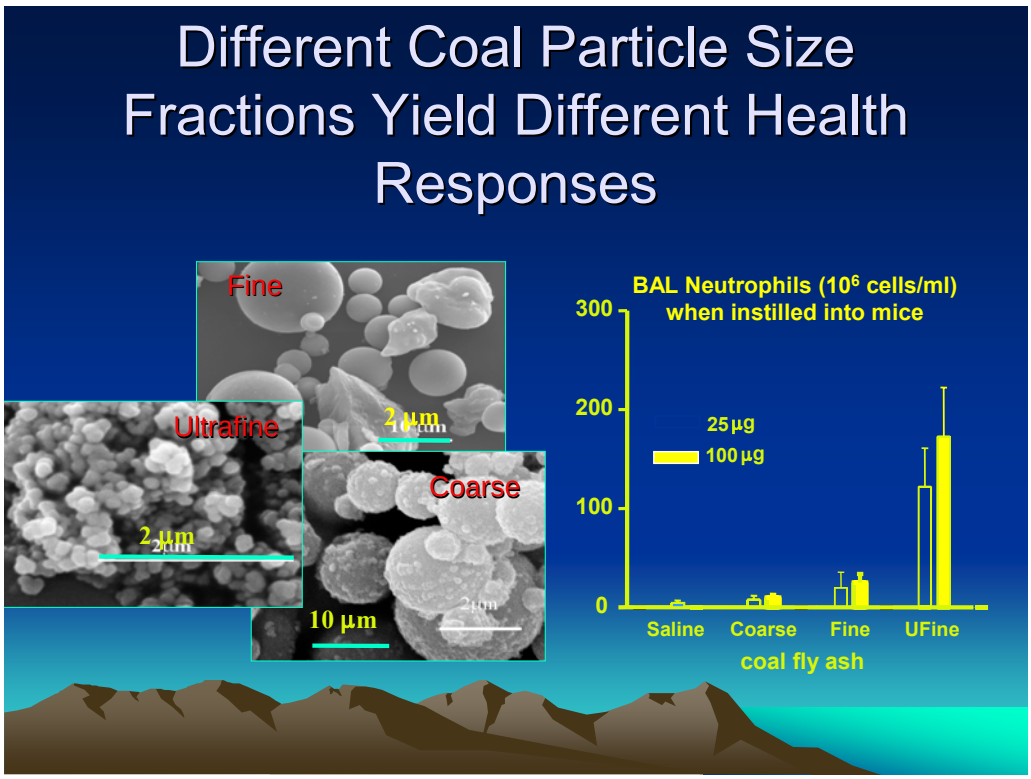
Next Step – Coal

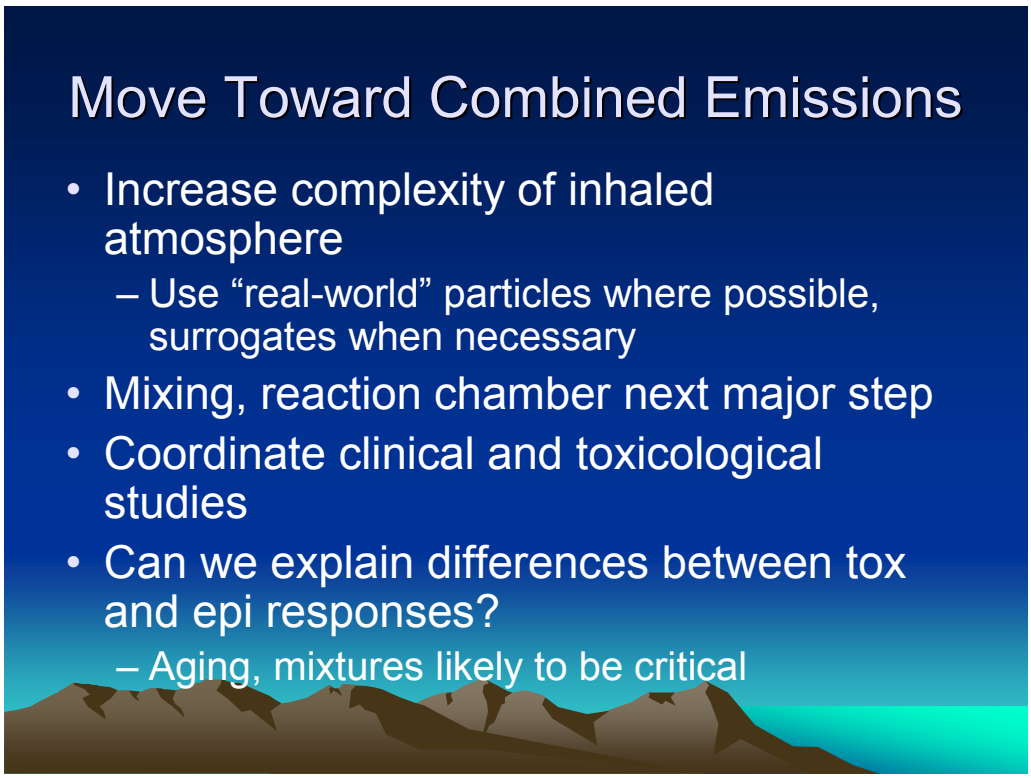
- Interest focused on metals
- Believe UF coal particles are formed in same manner as in oil combustion
- Hypothesis is that the UF coal particles will have a higher biological impact than coarse particles due to composition differences

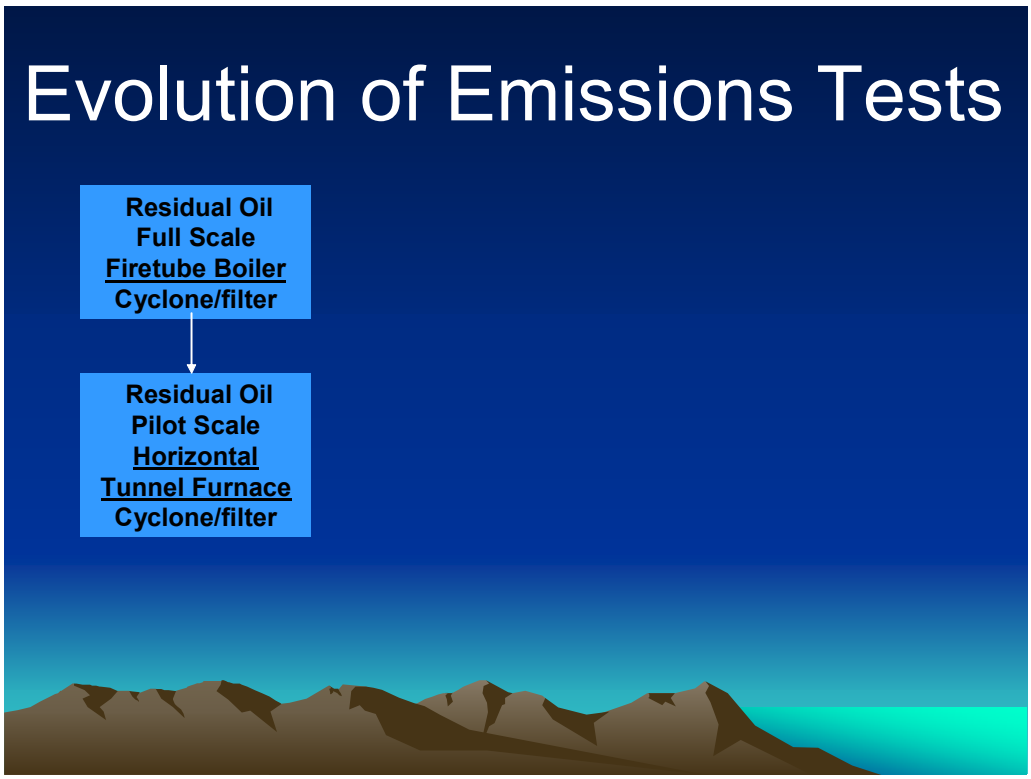
Detailed look at coal PSDs show ultrafine, fine, and coarse modes. Fine mode not clearly seen in many previous studies.

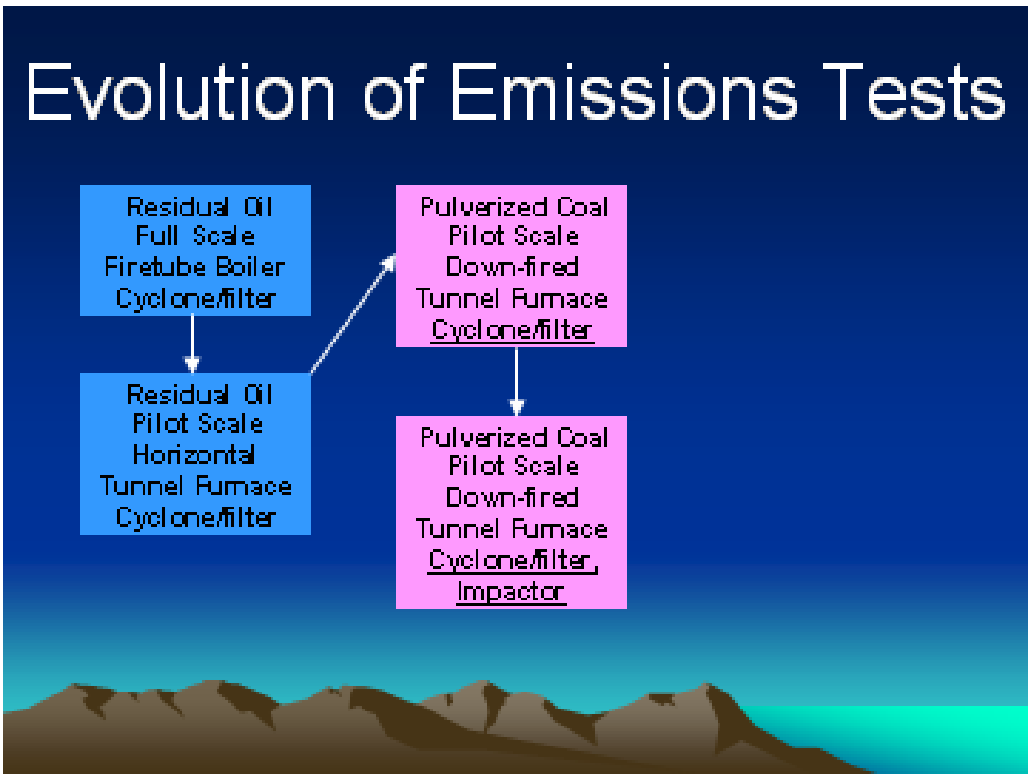


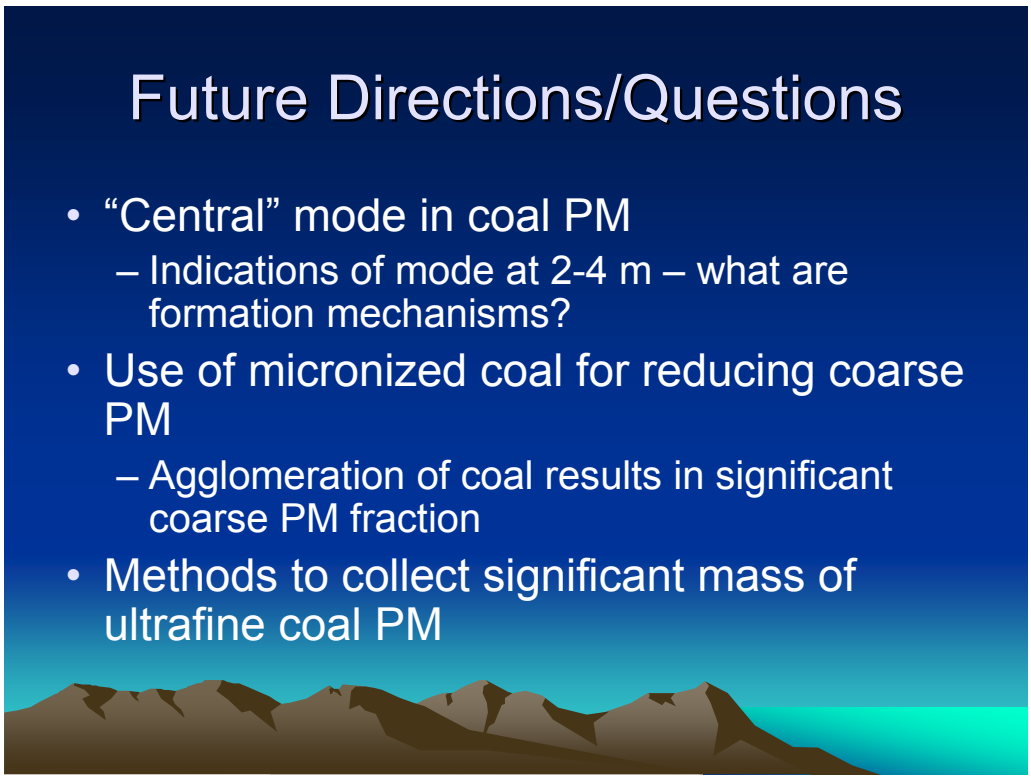

Different Coal Size Fractions Have Different Chemical Composition
Bituminous coals
Pittsburgh #8
Illinois #6
E. Kentucky
Ohio blend
Subbituminous coal and lignite
Wyodak PRB
North Dakota
dX/dlog Dp (mass fraction)
Aerodynamic diameter, Dp (µm)
Ohio blend
Wyodak PRB
Trace
Na
Mg
Ca
Fe
Al
Si

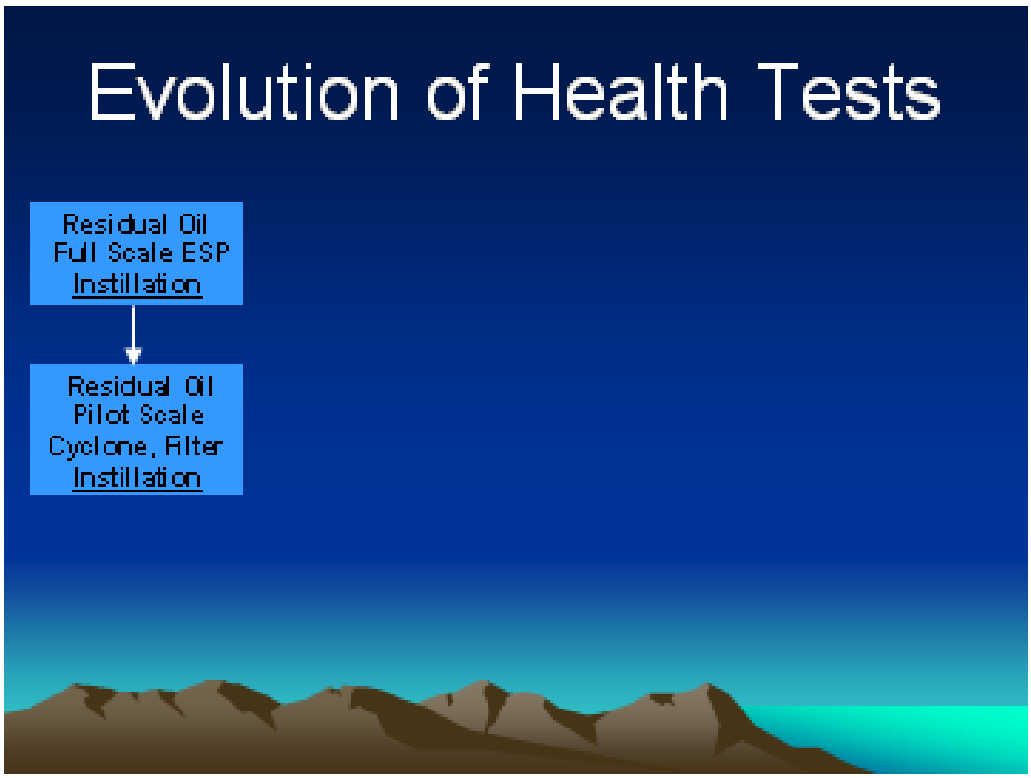

Different Coal Particle Size Fractions Yield Different Health Responses
Fine
Ultrafine
Coarse
2 µm
10 µm
BAL Neutrophils (10⁶ cells/ml) when instilled into mice
25 µg
100 µg
Saline
Coarse
Fine
UFine
coal fly ash

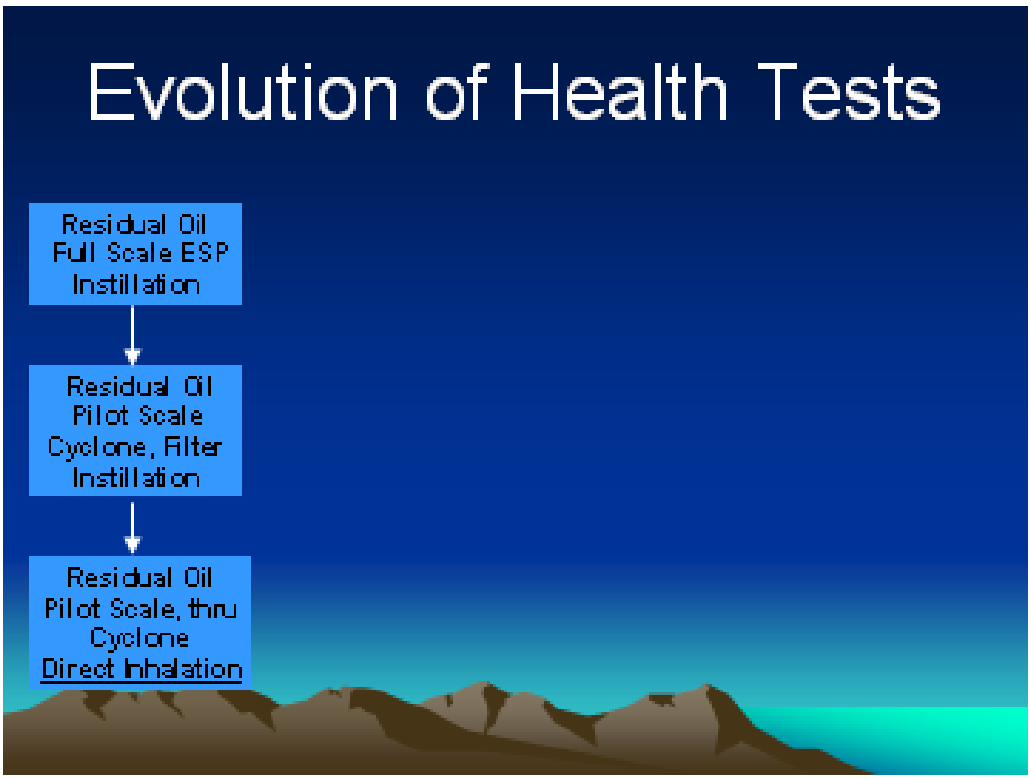

Move Toward Combined Emissions
• Increase complexity of inhaled atmosphere
– Use "real-world" particles where possible, surrogates when necessary
• Mixing, reaction chamber next major step
• Coordinate clinical and toxicological studies
• Can we explain differences between tox and epi responses?
– Aging, mixtures likely to be critical

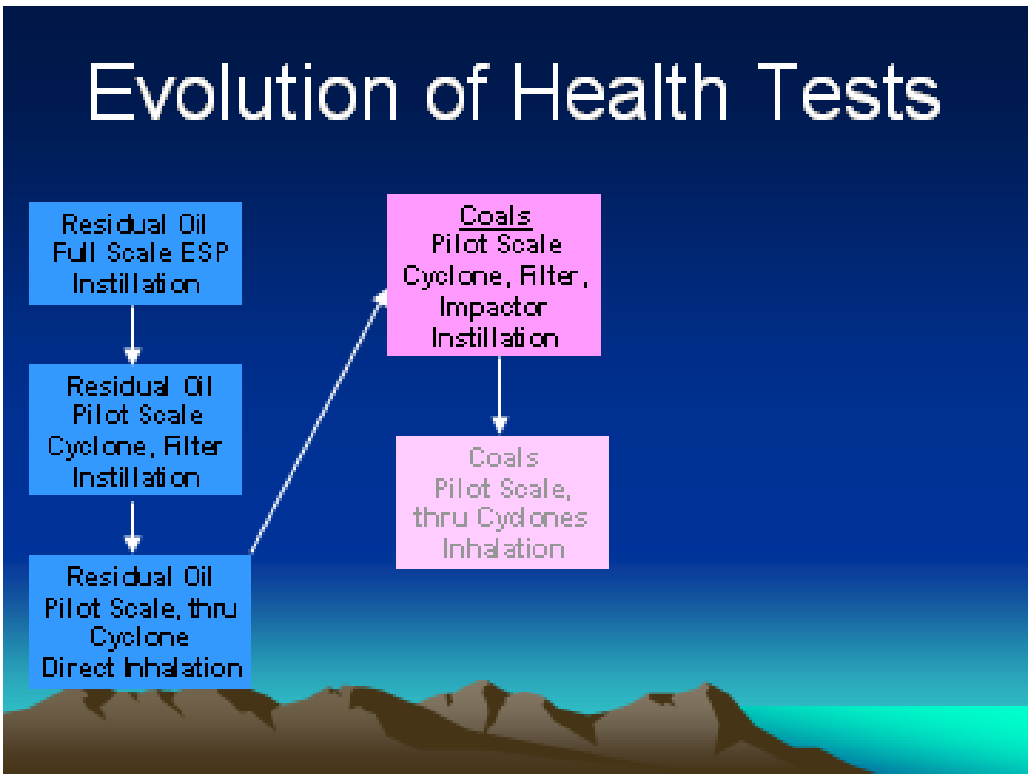

Evolution of Emissions Tests
Residual Oil
Full Scale
Firetube Boiler
Cyclone/filter
Residual Oil
Pilot Scale
Horizontal
Tunnel Furnace
Cyclone/filter

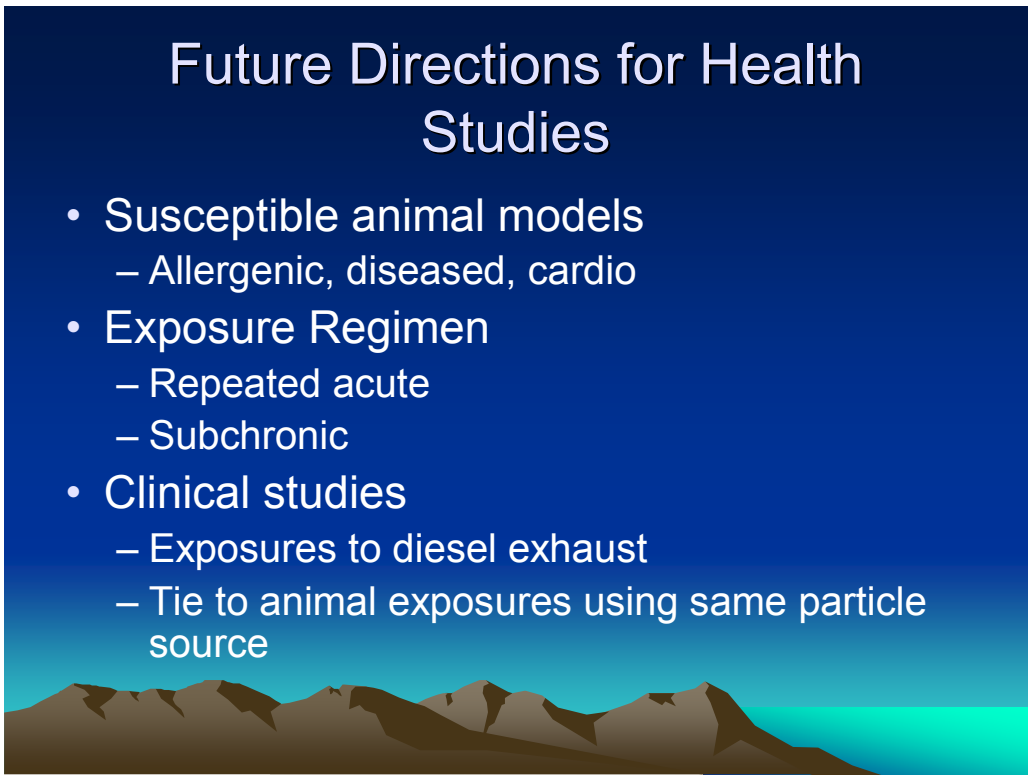

Evolution of Emissions Tests
Residual Oil
Full Scale
Firetube Boiler
Cyclone/filter
Residual Oil
Pilot Scale
Horizontal
Tunnel Furnace
Cyclone/filter
Pulverized Coal
Pilot Scale
Down-fired
Tunnel Furnace
Cyclone/filter
Pulverized Coal
Pilot Scale
Down-fired
Tunnel Furnace
Cyclone/filter,
Impactor

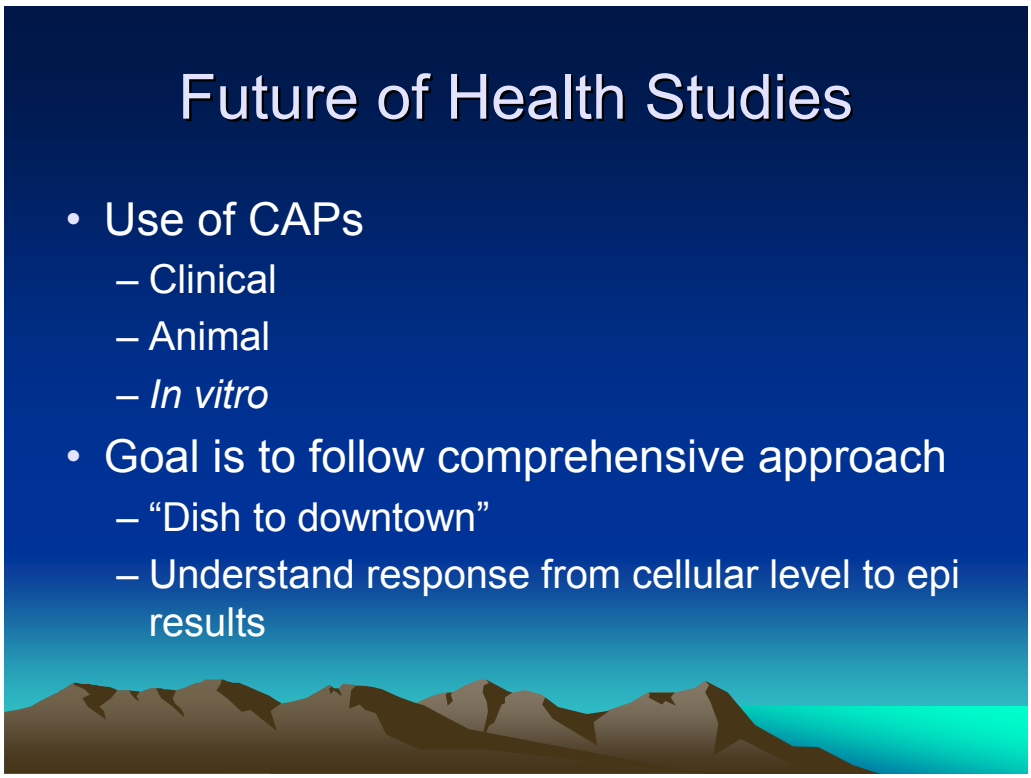

Future Directions/Questions
• "Central" mode in coal PM
– Indications of mode at 2-4 m – what are formation mechanisms?
• Use of micronized coal for reducing coarse PM
– Agglomeration of coal results in significant coarse PM fraction
• Methods to collect significant mass of ultrafine coal PM

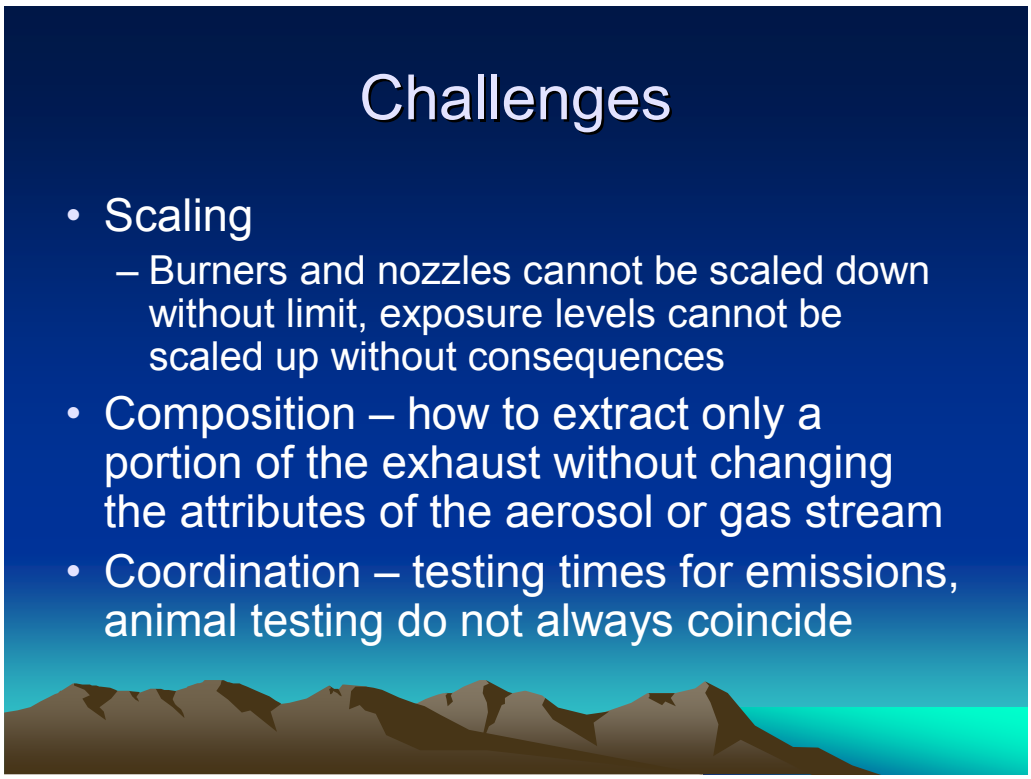

Evolution of Health Tests
Residual Oil
Full Scale ESP
Instillation
Residual Oil
Pilot Scale
Cyclone, Filter
Instillation


Evolution of Health Tests
Residual Oil
Full Scale ESP
Instillation
Residual Oil
Pilot Scale
Cyclone, Filter
Instillation
Residual Oil
Pilot Scale, thru
Cyclone
Direct Inhalation


Evolution of Health Tests
Residual Oil
Full Scale ESP
Instillation
Residual Oil
Pilot Scale
Cyclone, Filter
Instillation
Residual Oil
Pilot Scale, thru
Cyclone
Direct Inhalation
Coals
Pilot Scale
Cyclone, Filter,
Impactor
Instillation
Coals
Pilot Scale,
thru Cyclones
Inhalation


Future Directions for Health Studies
• Susceptible animal models
– Allergenic, diseased, cardio
• Exposure Regimen
– Repeated acute
– Subchronic
• Clinical studies
– Exposures to diesel exhaust
– Tie to animal exposures using same particle source


Future of Health Studies
• Use of CAPs
– Clinical
– Animal
– *In vitro*
• Goal is to follow comprehensive approach
– "Dish to downtown"
– Understand response from cellular level to epi results


Challenges
• Scaling
– Burners and nozzles cannot be scaled down without limit, exposure levels cannot be scaled up without consequences
• Composition – how to extract only a portion of the exhaust without changing the attributes of the aerosol or gas stream
• Coordination – testing times for emissions, animal testing do not always coincide